

Program for Enlightened and Productive Creativity Illustrated With a Moiré Patterns Lesson

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Combining both the Western perspective of creativity as productivity and the Eastern perspective of creativity as enlightenment, a Program for Enlightened and Productive Creativity (PEPC) for teaching inquiry was devised. The PEPC describes stages through which a student is guided to solve a problem using increasingly complex observation, inquiry, and experimentation. The use of this model in teaching is illustrated through a physics lesson of moiré patterns using overlapping patterns found in our everyday life. A case is made that PEPC can be applied to teaching general students, as well as gifted students, and in different content areas.

Educators around the world are becoming increasingly interested in infusing creativity into the curriculum (Chao, 2002). In addition to recognizing the potential benefits to society of preparing creatively productive students, educators are realizing the motivational benefits of creative teaching and learning for students. At the same time, educators from the East and West are looking to learn lessons from each other about effective teaching. The traditional view of creativity in the East differs from that of the West in that it emphasizes personal enlightenment as the ultimate goal of creative inquiry.

In the West, the emphasis has been on creating a product, even if that product is intangible, such as a theory or social order (cf. Gardner, 1993). Creativity is usually defined as the ability to produce work that is novel, original or unexpected, appropriate, useful, or adaptive concerning task constraints (Barron, 1988; MacKinnon, 1962; Perkins, 1981; Stein, 1953). In contrast, in the East there is a focus on personal expression or understanding of an inner sense of ultimate reality (Chu, 1970; Kuo, 1996; Mathur, 1982). This includes a focus on meditation as a method to achieve these goals (Sarnoff & Cole, 1983).

However, the creative goals of the East and West are not as far apart as they may initially seem. Although Zen Buddhism

has advocated turning inward in the search for higher consciousness (Gaskins, 1999), the work of Maslow (1968) in describing B-Cognition in *Peak Experiences* (pp. 74–96) and Csikszentmihalyi (1990) in describing Flow are very reminiscent of the state of being when seeking enlightenment in the Eastern sense. If the goals of the East and West are combined, both the internal goal of personal enlightenment and the external goal of productivity can be reached. This combination is what the model is designed to accomplish.

Theoretical Background and Components

Spiral Curriculum

Bruner (1960) proposed a “spiral curriculum” concept to facilitate structuring a curriculum around the great issues, principles, and values that society deems worthy of continual concern. He described this spiral curriculum as an appropriate way to teach highly structured bodies of knowledge like mathematics, physical sciences, and even the field of history (Bruner, 1960). Bruner’s spiral curriculum model has since been applied in many fields. For

example, DiBiasio and colleagues (DiBiasio, Clark, Dixon, Comparini, & O'Connor, 1999) applied Bruner's spiral model in a chemical engineering curriculum to emphasize learning through engagement in open-ended projects while revisiting concepts periodically with "ever-increasing sophistication" (p. 15). The innovative curriculum was intended not only to increase technical proficiency, but also to retain more students in the program by improving teamwork skills, motivation, interest, and confidence (DiBiasio et al., 1999). Because the scientific method can be seen as a continuous loop of steps, the steps should be repeated or jumped over according to the problem, like in the spiral curriculum. In this paper, we present a spiral creative model used in the process of scientific inquiry for enlightenment by using overlapped patterns. This Program for Enlightened and Productive Creativity (PEPC) is described as quantum stages through which one might advance to the next level according to the individual's ability.

Creative Problem Solving Process

There are three ways to view the creative process (Davis, 1992). The traditional approach is to describe a sequence of stages through which one solves a problem creatively. For example, Wallas' (1926/1976) four steps of *preparation*, *incubation*, *illumination*, and *verification* is perhaps the best-known sequence. Second, the creative process can be viewed as a change in perception, literally "seeing" new idea combinations, new relationships, new meanings, or new applications that simply were not perceived a moment before. A third approach to understanding the creative process is to examine a thinking technique used by individuals to produce new idea combinations and relationships that result in creative ideas and products (Davis, 1992).

The Creative Problem Solving (CPS) model is an extremely useful set of five stages oriented by Osborn (1963). The three core steps of *fact finding*, *idea finding*, and *solution finding* comprise the most basic form of CPS. However, these basic steps have been expanded for use in many situations over the years (Treffinger & Isaksen, 2004). For example, Diane Trantham, a featured NOVA teacher in Spring 2005 (NOVA, 2005), has expanded the steps for her educational purposes to: "1. Mess Finding: objective identification; 2. Fact Finding: fact gathering; 3. Problem Solving: problem examination; 4. Idea Finding: idea development; 5. Solution Finding: idea evaluation; and, 6. Acceptance Finding: idea implementation" (§ 4). The Program for Enlightened and Productive Creativity illustrated here is composed of five steps: (1) finding the

problem, (2) restructuring, (3) solving the problem, (4) applying results, and (5) enlightenment.

Relationship Between Scientific Inquiry and Creative Ability

Scientific inquiry is founded on the processes of experimentation and observation to find solutions to questions about all natural phenomena. The general method of scientific inquiry usually begins with a question, which is raised while observing some natural phenomenon (National Research Council, 2000). Then, scientific experiments are devised to resolve the answer to the question. Often, experiments are repeated and redesigned. Through creativity, scientists continually refine the existing scientific laws, theories, and models to better match experimental results, and to better predict natural phenomena. Once a scientific question has been posed, a scientist considers all plausible hypotheses or explanations that might answer the question raised and designs experiments to test them. The key to designing successful experiments is the identification of all variables relevant to both the observed phenomenon and the question posed. Ideally, a scientific experiment is one in which all experimental variables except one are controlled by the experimenter (Hestenes, 1987).

Generally scientists apply the following five-step processes in their scientific inquiry: define a problem, form a hypothesis, observe and experiment, analyze data, and draw conclusions. All scientists answer questions with a sequence of problem-solving skills called the scientific method. Some of these skills include defining the problem, forming a hypothesis, making observations, performing experiments, analyzing data, drawing conclusions, and communicating results. The answers to questions may change as scientists design better experiments and make new observations (McFadden & Yager, 1993).

Elements of Creative Thinking

Psychologists have identified many basic elements of creativity. Four of these elements are the classic Guilford/Torrance fluency, flexibility, originality, and elaboration, which can be measured by the Guilford (1967) tests and the Torrance Tests of Creative Thinking (Torrance, 1966, 1998). Some scholars have tried to classify creative abilities as intellectual or affective abilities (Ha & Moon, 1997). However, it is difficult to isolate mental abilities that have nothing to do with creative abilities. It is also very difficult to classify two categories of creative abilities without an evident criterion for the classification. For example, many consider motivation to be an affective component, but

there is an undeniable cognitive component to motivation. Nonetheless, several main elements of creativity are described as the following abilities (Goff, 1998; Torrance & Myers, 1970). Although not a comprehensive list of creative abilities, the abilities below were chosen because they are the ones most clearly developed through the PEPC:

1. Fluency: to produce many ideas in response to an open-ended problem or question.
2. Flexibility: to take different approaches to a problem, think of ideas in different categories, or view a situation from several perspectives.
3. Originality: to express uniqueness, nonconformity.
4. Elaboration: to add details to a given idea; developing, embellishing, and implementing the idea.
5. Sensitivity to problems: to find problems, detect difficulties, detect missing information, and ask good questions.
6. Problem defining: to identify the “real” problem, isolate the important aspects of a problem, clarify and simplify a problem.
7. Visualization: to fantasize and imagine, “see” things in the mind’s eye, and mentally manipulate images and ideas.
8. Ability to regress: to think like a child, without being cluttered by regulation and the firm knowledge of “how it ought to be done.”
9. Analogical thinking: to relate ideas from one context and to those in another context.
10. Analysis: to analyze details, separate a whole into its parts.
11. Synthesis: to see relationships, combine parts into a workable whole.
12. Transformation: to adapt something to a new use, see new meanings, implications, and applications, or change one object or idea into another creatively.
13. Extend boundaries: to go beyond what is usual, to use objects in new ways.
14. Intuition: to make spontaneous leaps or perceive relationships based upon insufficient information.

The Importance of Physics Education for Enlightenment and Productivity

A goal of physics education is that all students should experience the amazing and enlightening phenomena of the physical and natural world in which they live. Moreover, physics teachers should offer the opportunity for students to discover for themselves the relationships of several phenomena through discovery of their world. They should also explain how human beings can have an affect on the natural and physical worlds. This can be accom-

plished through physics experiments and observations. However, in many classes, students realize that the most important learning in physics education is memorized in knowledge, concepts, and mathematical formulae without discovery. As a result, many students do not like to choose physics as an elective.

American students’ general dislike for mathematics and science courses was noted in the recent U.S. Department of Education (USDE; 2006) report, *Meeting the Challenge of a Changing World: Strengthening Education for the 21st Century*. One dire prediction of this trend was that, by 2010, only 15% of the world’s science and engineering doctorates would come from the U.S. (p. 3). The report called for the same emphasis on science and mathematics that followed the Sputnik scare in 1957. However, there are some indications that the movement away from science and mathematics is not just a Western trend. The widespread dislike for mathematics and science had become so well-known in Japan by 1998 that they coined the terms *risu girai* for “hate of math-science” and *risu banare* for “fleeing math and science.”

Nonetheless, our society deems that science and technology play an increasingly important role in all aspects of our everyday lives, and physics is the most basic subject in science and technology. Therefore, it is imperative that we focus on enhancements to develop students’ creative ability and confidence in solving problems through the use of physical laws, as well as encourage them to discover truths about their world through observation. The experience of insight and enlightenment appears when students are strongly stimulated to think in a new way and to use visual and creative thinking.

There are four approaches to the identification of creative talent in scientifically gifted students (Taylor & Barron, 1964) based upon Rhodes’ (1961) Four Ps of Creativity: (a) the product created, (b) the process of creating, (c) the person of the creator, and (d) the environment in which creation takes place. As a result, the Program for Enlightened and Productive Creativity was designed with consideration of the above four approaches.

The Relation Between Insight and Enlightenment

A physicist discovers a new principle, law, or theory through insight and enlightenment by observing the everyday world. Therefore, we need to teach our students to have the ability of insight and enlightenment in our classrooms or everyday life. Wallas (1926/1976) and Hadamard (1949) gave us a splendid discussion of the phenomenon of insight. They identified four distinct stages that seem to occur in every documented case of scientific insight:

preparation/“stirring up of ideas”; incubation/unconscious search for ideas; illumination/noticing a solution; and verification/checking the solution (see Langley & Jones, 1988, for a comparison of these and other similar models; p. 191). These stages and their characteristics constitute a set of empirical generalizations relating to insight, and any successful theory must account for their existence.

Scientific insight is the “Aha” experience that produces exclamations like the “Eureka!” of Archimedes (Sternberg, 1988). This scientific insight is always the action of each process along the way: preparation, incubation, and illumination. But, enlightenment reveals that all of the separate parts of the universe are manifestations of the same whole. Enlightenment is one state of being; it is whole and unified. Therefore, the final goal of physics education is facilitating the enlightenment of the students themselves.

Overlapped Patterns in Our Everyday Lives

Repeated regular structures can be easily observed in our everyday lives. If we are concerned about these repeated regular structures, we can find more and various types of the repeated regular structures around us. When we overlap two or three repeated regular structures, we can observe new, larger overlapped patterns as water waves or other strange shapes. These overlapped patterns are called moiré patterns. This moiré effect is a well-known phenomenon that occurs when repetitive structures are superimposed or viewed against each other. It consists of a new pattern of alternating dark and bright areas, which is clearly observed at the superposition (Amidror, 2000; Patorski & Kujawska, 1993).

Theocaris (1969) said that these moiré patterns are a kind of intensity interference that can be acquired using incoherent light sources. There are various types of gratings such as parallel lines (Yuk & Chang, 2001; Yuk, Jo, & Chang, 1994), criss-crossed (Yuk, Ryu, & Kim, 1995), circular (Song, Lee, Jo, Chang, & Yuk, 1998), radial, spiral (Yuk & Chang, 2001), elongated circular (Song et al., 1998), and matched radial parallel (Kim et al., 1997). According to the study by Takasaki (1970), there are shadow moiré and projection moiré techniques. We have widely used these moiré patterns for measurement of rigid body translation and angular displacement (Kim et al., 1997; Song et al., 1998), surface contour generation (Yuk et al., 1994), analysis of the three-dimensional moiré fringes (Yuk & Chang, 2001), refractive-index measurement (Nishijima & Oster, 1964), and computational imaging and vision (Amidror, 2000) in physics and technology. These moiré patterns are especially applicable to

physics education and art pattern design (Kim, Yuk, & Kim, 2003; Yuk et al., 1995).

We can easily make new overlapped patterns superimposed of two or three gratings of different combinations in our classrooms. Therefore, we can use the merits of these overlapped patterns in physics education for encouraging the creative ability of the gifted. Most of the students will obtain several new ideas and their creativity will develop through the practice of this program. Some scientifically gifted students can be guided to originate a new mathematical formula by observing these overlapped patterns, and they can be encouraged to find applications for it. For example, they can apply their formulas to architectural design, clothing design, art composition, decoration, measurement of the surface, and physical education materials (Amidror, 2000; Kim et al., 2003; Patorski & Kujawska, 1993).

Program for Enlightened and Productive Creativity

Explanation of Creative Model and Structure

In 1918, Plank was awarded the Nobel Prize in physics for his study on the establishment and development of elementary quantum theory. Almost 100 years after his discovery, today's society is changing from a linear continuous process to a nonlinear leaping quantum society. Students ought to be given an opportunity to jump up to the upper level in order to succeed in today's world. Thus, we are applying a nonlinear quantum spiral model for encouraging the creative ability of scientifically gifted students.

The Chinese word for physics (物理=物+理) has a figurative meaning related to the process of enlightenment (Zukav, 2001). We can obtain enlightenment from the providence of nature in the process of physics inquiry. Enlightenment is the final process, and insight is always the action of each process along the way: finding the problem, restructuring it, solving the problem, applying the results, and, finally, enlightenment. The final goal of physics education is enlightenment. But, it is also a temporary goal because enlightenment can lead to other questions and inquiries. And, the Program for Enlightened and Productive Creativity, which will be illustrated with overlapped patterns in physics education, is described with five levels of content complexity. The levels, progressing from simpler to more complex, are: (a) general overlapped patterns, (b) parallel line grating, (c) circular grating, (d) radial grating, and (e) spring wire grating.

Creative Program Model for Enlightenment by using Overlapped Patterns in Physics Education

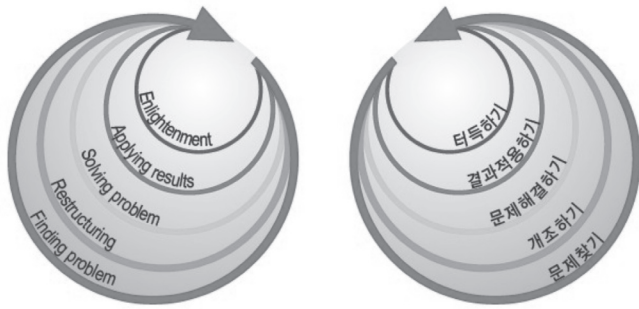


Figure 1. Schematic drawing of the Program for Enlightened and Productive Creativity

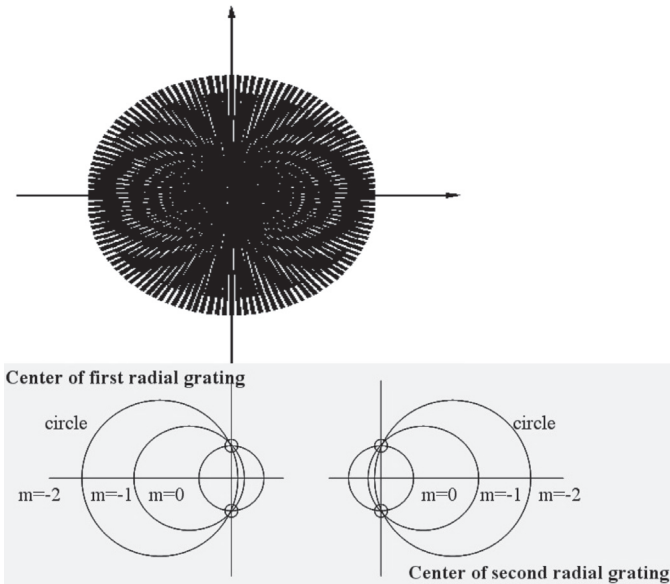


Figure 2. Schematic drawing of the overlapped two radial gratings

As shown in Figure 1, this program is described in quantum stages through which one might proceed in solving a problem creatively, and is composed of five steps with symmetrical spiral types: (a) finding the problem, (b) restructuring the problem, (c) solving the problem, (d) applying results, and (e) enlightenment. Because the scientific method is not only a straight line of steps but also a continuous loop, as well, the steps of the scientific method should be repeated or jumped over according to the situation of the problem. This idea is obtained from the overlapped patterns by the superimposition of two radial gratings.

If we overlap two radial gratings, as shown in Figure 2, we can find overlapped patterns with symmetrical type in several discontinuous circles formed by the superposition of the two radial gratings. These symmetrical spiral types look like a form of symmetrical turbulence that all aircraft generate while they are flying. Symmetry seems to be absolutely fascinating to the human mind. We can eas-

ily look at symmetrical things in nature. Moreover, physics is extremely interesting in that there seems to be a deep connection between the many physics laws and symmetry laws (Feynman, 1965).

The spiral shape on the left side represents left-brain thinking and the spiral shape on the right side represents right-brain thinking. These two ways of thinking have kept a complementary mutual balance. The color of both circles represents a rainbow color pattern, the gate toward the ideal world for the enlightenment. The rainbow is composed of seven colors and the three primary colors of the white light are red, green, and blue (Minnaert, 1954; Newton, 2003). In this model, red, orange, yellow, green, and blue colors represent a white light that is the meaning of enlightenment.

Applying the Main Elements of the Creative Abilities in the Problem Solving Steps of the PEPC

As mentioned previously, the PEPC is composed of five steps and creative abilities can be observed in each of the steps. In the first step, the *problem-finding step*, we can measure fluency, flexibility, and sensitivity, because students have to find repeated regular structures in our everyday life and categorize each repeated regular pattern by similar forms. In the second step, the *restructuring of the problem*, we can measure flexibility, originality, visualization, analogical thinking, and ability to regress because students have to practice superimposing each two or three gratings in order to make new overlapped patterns and categorize each overlapped patterns by similar forms. Moreover, flexibility, originality, elaboration, and problem defining can be measured in the *problem-solving step*, as students have to discover various structural regularities by using experimentation and observation, and representing a mathematical formula for new overlapped patterns. In the *applying results* step, we can measure elaboration, transformation, and extended boundaries when students have to find application of overlapped patterns in everyday life or in their physics classroom. Finally, we can measure intuition and synthesis in the *enlightenment* step because students have to obtain a conclusion and a new awakening through the practice of this program and experience the "Aha." This last step is the most important step in the PEPC, because the final goal of the physics education is enlightenment.

Example of the PEPC Using Overlapped Patterns

First Step: Finding a Problem (Using Fluency, Flexibility, Sensitivity). The first step in solving a problem is becom-

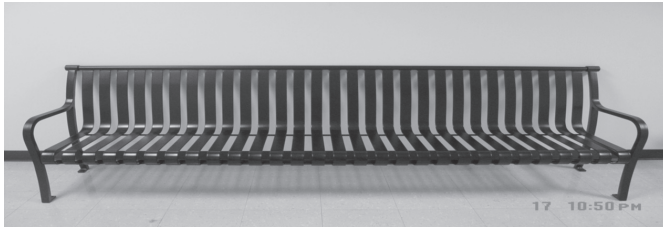


Figure 3. Repeated regular patterns found in our everyday life

ing sensitive to it. So, students should be shown a few examples of overlapping patterns in their everyday lives, as illustrated in Figure 3.

Then, instruct the students to take pictures, cut from magazines, or draw as many examples of repeated regular patterns found in their environment as they can, but they should include at least nine (fluency). Encourage them to find as many different examples as possible (flexibility). Examples could include a curtain, nylon stocking, summer clothing, bag, briefcase, shirt, chessboard, baduk board, notebook, roof, air conditioner, computer, air blower, film case, automobile, and the like.

Be sure that you have cards depicting some additional examples of repeated regular patterns that represent each of the following forms: parallel line, crossed, circle, and radial. After students examine a couple of your examples of each form and can differentiate them, have them work in groups of three or four to categorize their cards by form. Patterns in each form are shown in Figures 4–7.

1. *Parallel line form* examples include a terrace roof, trashcan, building, curtain, briefcase, shirt, roof, air conditioner, stairs, water wave, bridge, TV, bamboo blind, and cooker cap. The first three examples in parallel line form are shown in Figure 4.
2. *Crossed form* examples include a chair, sculpture, chessboard, stocking, summer clothing, shirt, baduk board, radiator, mosquito net, driving range net, ceiling, and shopping basket. The first three examples of crossed form are shown in Figure 5.
3. *Circle form* examples include a tree base, ventilator, water wave, a computer, pencil case, target, and bus stop. The first three examples of circle form are shown in Figure 6.
4. *Radial form* examples include a ventilator, fan, lampshade, air blower, film case, electric fan, and bicycle. The first three examples of radial form are shown in Figure 7.

Second Step: Restructuring the Problem (Using Flexibility, Originality, Visualization, Analogical Thinking, and Ability to Regress). Put some of the pictures of the different types of



Figure 4. Repeated parallel line forms found in our everyday life



Figure 5. Repeated crossed forms found in our everyday life

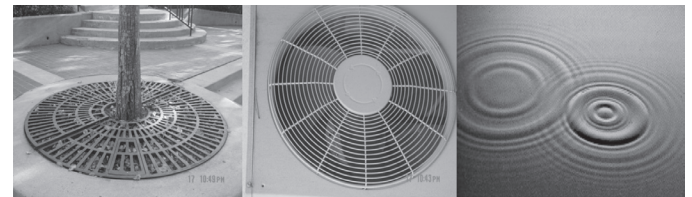


Figure 6. Repeated circle forms found in our everyday life



Figure 7. Repeated radial forms found in our everyday life

patterns on transparencies and demonstrate how new patterns are formed by overlapping the pictures of two different patterns. Then, ask students to again bring in pictures from their environment of new patterns generated from overlapping repeated regular patterns. Stress the value of finding as many and as different patterns as possible. You may even want to give a small reward to the student who brings in the most illustrations and another to the student whose illustrations demonstrate the greatest versatility. It would be good to also recognize the illustration that is most unusual (originality) and the one that is hardest to see at first glance (visualization). Encourage the students to have fun with the assignment (ability to regress) and try to look at the world with fresh eyes, like a Martian new to Earth who is looking for repeated patterns (analogical thinking). Figure 8 illustrates some new patterns formed

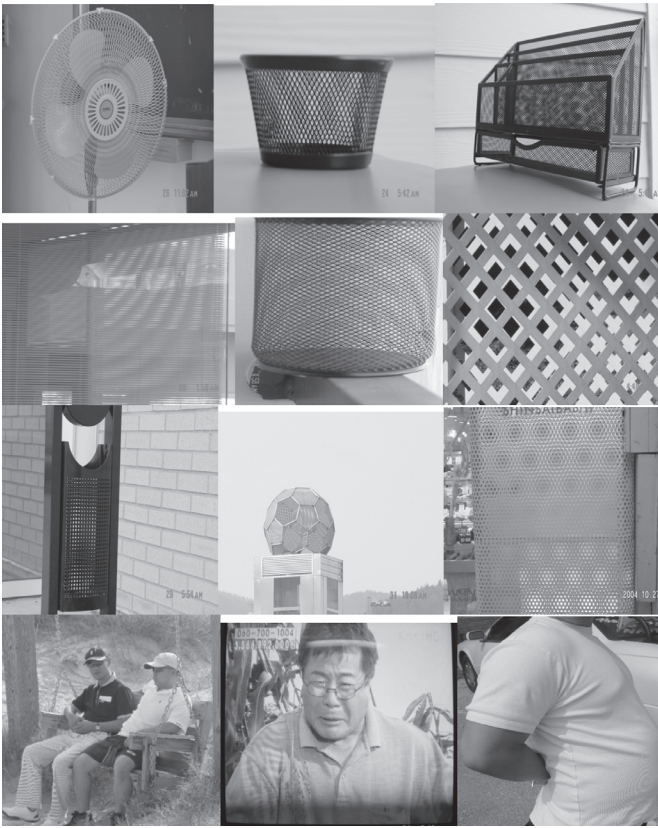


Figure 8. New patterns generated from overlapping repeated regular patterns found in our everyday life

from overlapping repeated regular patterns. These patterns might include a summer curtain, briefcase, stocking, summer clothing, bag, mosquito net, pencil case, bridge, electric fan, and the like.

Again, divide the students into groups to categorize the new patterns by similar forms. This time, allow them to develop the categories and give them descriptive names before you show them the prototypes and names as illustrated in Figures 9–12.

1. *Stripe fringe patterns* include a pattern on a TV screen, blinds, shirt, brief case, summer shirt, box, bridge, and TV. The first three examples of stripe fringe patterns are shown in Figure 9.
2. *Wave fringe patterns* include a pencil case, basket, sculpture, summer shirt, stocking, summer curtain, mosquito net, driving range net, shopping basket, and bamboo blind. The first three examples of wave fringe patterns are shown in Figure 10.
3. *Circular fringe patterns* include an electric fan, sculpture, shirt, pencil case, and driving range net. The first three examples of circular fringe patterns are shown in Figure 11.
4. *Rectangular fringe patterns* include a decoration, trash box, card case, pencil case, bus stop, electric fan, and



Figure 9. New stripe fringe patterns found in our everyday life



Figure 10. New wave fringe patterns found in our everyday life

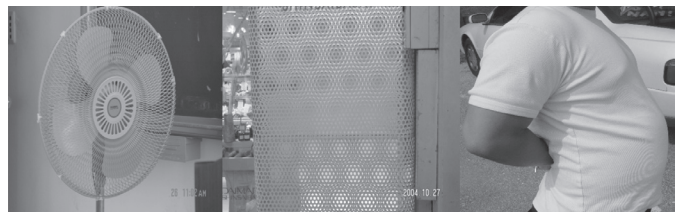


Figure 11. New circular fringe patterns found in our everyday life

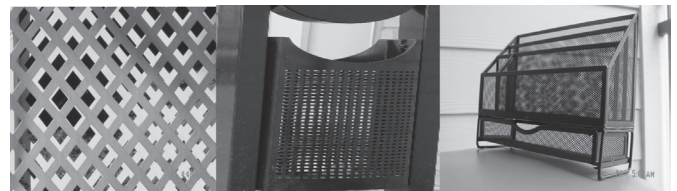


Figure 12. New rectangular fringe patterns found in our everyday life

driving range net. The first three examples of rectangular fringe patterns are shown in Figure 12.

Third Step: Solving the Problem (Using Originality, Flexibility, Elaboration, and Problem Defining). At this step, the students will begin to form rules about the patterns' structural regularity based upon observation and experimentation. Distribute two parallel line gratings printed on transparent papers to each student and ask, "Why do you think these new patterns were generated when two repeated regular patterns were overlapped?" Allow students time to conjecture, and then show them some patterns regularly generated when two parallel line gratings are overlapped (see Figure 13).

Ask students to make predictions about the physical properties of the new patterns and record these predic-

tions for all to see. Then, give them the measuring tools and images of overlapped patterns to test their predictions. Have them record whether each prediction was disproved or not, and list any additional observations that they make. These should include:

1. X-shaped lines are bright fringes, and N-shaped lines are dark fringes.
2. The distance between each fringe is proportional to the distance between two consecutive grating lines.
3. The distance between each fringe is inversely proportional to the angle created by overlapping two gratings.
4. The distance between each fringe is always larger than the distance between two consecutive grating lines.
5. New fringes always generate perpendicular to grating lines.

Then, distribute two crisscrossed gratings printed on transparencies to each student and ask the students to record observations about the patterns generated when these images are overlapped. Allow students to illustrate patterns generated when two crisscrossed gratings are overlapped (see Figure 14).

Using measuring tools for observation and experimentation with the patterns, students should be able to test their original predictions and discover that rules 2–5 are obtained. Students should be able to anticipate that they will do the same with two overlapping circular gratings, so have them manipulate the circular gratings to make overlapped patterns (see Figure 15).

Students should record and share their observations of the overlapped circular gratings. Alert them to listen carefully to each other's observations so that they can verify or disprove them. They should be able to list the following observations:

1. New fringes are unrelated to angle.
2. The shapes of new fringes are straight lines.
3. The shapes of new fringes are always symmetric with any other fringe created by the overlap.
4. Fringe lines increase or decrease according to the length between the centers of the circles.

In the last activity of this type, distribute two radial gratings printed on transparencies to each student. They should be able to overlap the images to form new patterns such as those in Figure 16.

Then, ask the students to list and test their observations, resulting in a list like this:

1. The shape of the new fringes is spider shaped or butterfly shaped.
2. The shape of the new fringes is circular.

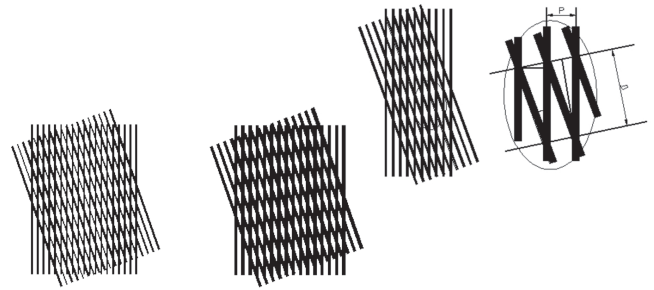


Figure 13. Patterns of regularity generated when two parallel line gratings are overlapped

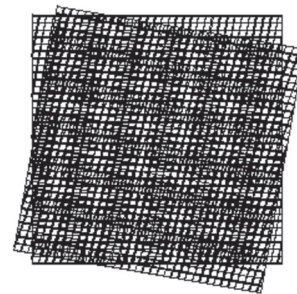


Figure 14. Patterns of regularity generated when two crisscrossed gratings are overlapped

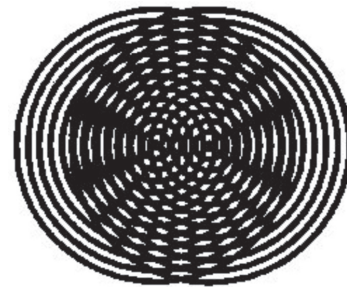


Figure 15. Patterns of regularity generated when two circular gratings are overlapped

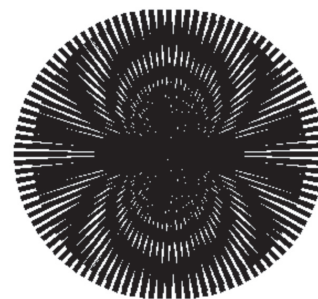


Figure 16. Patterns of regularity generated when two radial gratings are overlapped

3. New fringes of the circular type always pass two central points of the radial gratings.
4. The shape of new fringes is always symmetric with any other fringe created by the overlap.

In the beginning, students may need some help with forming such rules, so you should prepare a lab sheet that guides their observations. For example, each type of overlapped form would be a heading and under each heading there would be sentences with blanks, such as:

Patterns of Regularity Generated When Two Radial Gratings Are Overlapped

1. The shape of new fringes is like two common animals. What are they?
2. New fringes of the circular type always pass two _____ of the radial gratings.

However, students who can generate meaningful rules without such aids should be encouraged to do so. In fact, even among very bright students, there is often a need to differentiate tasks. So, you could have three levels: (1) a sheet with very pointed questions and statements as above; (2) a sheet with statements that offer less guidance, such that the first statement above might be: What are the shapes of new fringes?; and (3) a sheet that just has the headings for the different forms with room for the students to write any observations. Students should be encouraged to work at the level where they can be successful, but they should be prodded to move toward less guidance.

Fourth Step: Applying Results (Using Elaboration, Transformation, and the Ability to Extend Boundaries). This is the “so what?” step whereby students find applications for the rules that they have discovered. They are given the task of finding applications of overlapped patterns by using two parallel line gratings (see Figure 17), crisscrossed gratings (see Figure 18), circular gratings (see Figure 19), and radial gratings (see Figure 20) that they might find in their everyday life or in the physics classroom.

Some examples of applications that they may consider for overlapped parallel line gratings include measuring the height of a circular cone or regular tetrahedron; measuring the height of the nose or the breast; representation of the refraction in water waves; new clothes design; uses in designing anti-aliasing techniques for sound recording and photographic images; and contour maps (see Figure 17).

Applications of overlapped patterns by using two crisscrossed gratings include new clothes design and representation of the reflection in water waves (see Figure 18).

Applications of overlapped patterns by using two circular gratings include new clothes design, representation of the interference in water waves, measurement of refractive indices, and measurement of linear displacement (see Figure 19).

Finally, applications of overlapped patterns by using two radial gratings are illustrated by new clothes design, representation of the electric field, and representation of the magnetic field (see Figure 20).

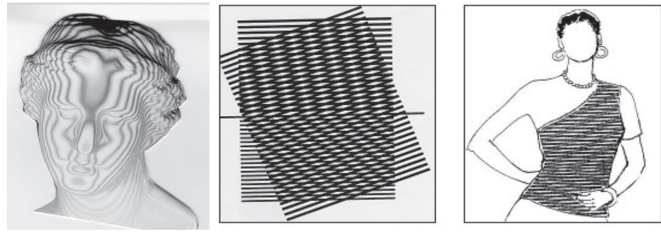


Figure 17. Application of overlapped patterns by using two parallel line gratings

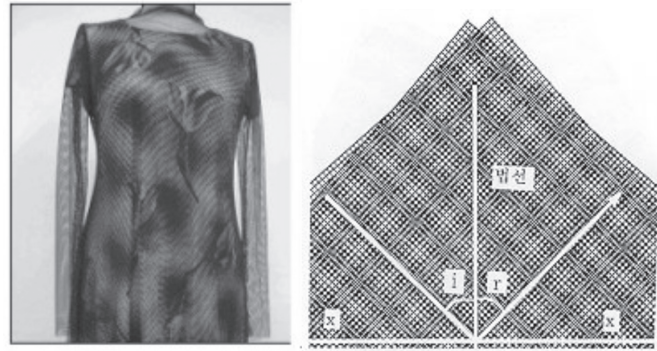


Figure 18. Applications of overlapped patterns by using two crossed gratings



Figure 19. Application of overlapped patterns by using two circular gratings

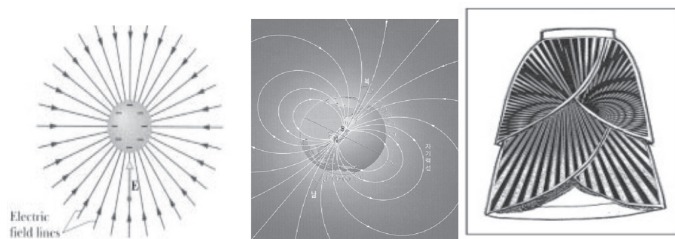


Figure 20. Application of overlapped patterns by using two radial gratings

At this point, students could expand their understandings based upon their observations by researching ways that moiré patterns are applied in various fields. By reading, searching the Internet, interviewing individuals from various fields, and other means, students should prepare to show some applications of the information they have learned.

Fifth Step: Enlightenment (Using Intuition and Synthesis). This is the step of concluding and awakening.

Scientific processes result in the act of discovery. In most cases, these discoveries take the form of insight. Students should be assisted to reflect upon their own processes and feelings during the program. You could ask them to think about questions such as these: Did you feel a “flash of insight” during the process of this program? When and at what point did it occur? How could you describe it? If you did not, can you think of another time when you did have an insight? What was different then? Students should have the opportunity to reflect upon these questions overnight or over a weekend before they are asked to share their responses.

On the day that the students are to share their reflections, be ready to give some examples of other thinkers who have described their understanding of a phenomenon as occurring in a flash of insight. Archimedes’ solution for weighing gold by water displacement; Kekule’s discovery of the benzene ring through dozing observation of smoke twisting up from the fireplace; and Poincaré’s discovery of an expression for Fuchsian functions while boarding a bus are three of the best known (Langley & Jones, 1988, pp. 179–180). However, the history of inventions can provide more of such insights, such as the Swiss hiker, George de Mestral, who examined burrs that stuck to his clothes under a microscope and had the inspiration to invent Velcro.

Open the discussion by allowing the students to summarize their observations and the results of their experiments with the overlapping images. Some of their conclusions may be similar to these:

1. There are many repeated regular patterns in our everyday lives.
2. If we overlap two or three repeated regular patterns, we can obtain various other patterns from the two overlapped patterns.
3. These various overlapped patterns are very useful in measuring the surface of height and volume.
4. These various overlapped patterns are very useful in designing new clothing in fashion.
5. We can apply these various overlapped patterns in the physics classroom.
6. We can apply these various overlapped patterns in art and design.
7. We realize that nature is composed of a great number of regular structured patterns.
8. We were deeply impressed with the various overlapped patterns.
9. We realize why some patterns look like they are moving when filmed on TV.

Then, guide students to go beyond these observations and think deeply about their physical and emotional feelings during the processes. Ask them if they have experienced an “Aha” that produces an exclamation like the “Eureka” of Archimedes. Share with them that physics (物理=物+理), in particular, has a figurative meaning of enlightenment because we can obtain enlightenment in the process of physics inquiry. Enlightenment is the final process and the insight comes from the parts of the process: finding a problem, restructuring the problem, solving the problem, applying results, and enlightenment. The final goal of physics education is enlightenment.

Encourage students to share any honest reactions that they have. Some may not like the open-ended nature of the process and may prefer traditional lectures. Share with them that growth causes discomfort and unease. Others may be puzzled and need more experiences to understand the concept. However, there may be some who have experienced enlightenment, and allow them to share any physical and emotional reactions.

If they seem reticent to discuss physical sensations and emotional reactions during discovery, introduce them to the ideas of Damasio, a neuroscientist and the author of *Descartes’ Error* (1994), a book refuting the separation of mind and emotion. Damasio has not only argued that the classical separation is false, but he has also proposed that the interaction of rational thought and emotional reaction allow us to think faster and make better, more rational, decisions. He has theorized that our emotional responses cause somatic responses, a warm relaxation or a tightening of the stomach, that cause our emotional system to create markers for an experience as positive or repellent. When a similar situation arises, we get a subliminal message that intuitively shapes our decisions without having to go through a long rational process (Johnson, 2004).

This is related to enlightenment in physics because there are anecdotes of great discoveries being preceded by a somatic “knowing” that the answer was forthcoming, even before it was conscious. LeDoux (1996) has demonstrated how our brains can detect danger before we are aware of the feeling of fear. Extending this example, he has claimed that the brain initiates somatic responses (e.g., rapid heart-beat, sweaty palms, muscle tension) before the conscious recognition of fear occurs. He explains, like Damasio, that this is due to response reactions being hardwired through experience. If students can learn to identify the feeling of a solution, and the feeling is positive, then they will be motivated to continue to research.

This brings us spiraling back to Bruner (1960), who claimed that scientists and other scholars often used intuitive thinking rather than strictly analytical thinking in

making great discoveries. The “Aha” experience that we have called enlightenment was very similar to what Bruner called intuition—the sudden knowing without necessarily knowing how.

Discussion

We have presented a Program for Enlightened and Productive Creativity for encouraging the creative ability of gifted students by using overlapped patterns found in our everyday life. Moreover, this program can apply to general students from elementary school to high school, as well as scientifically gifted students. The purpose of this PEPC is to obtain the enlightenment in everyday creativity by using overlapped patterns through the practice of nonlinear quantum spiral program in the classrooms or everyday life. We have described this creative program as a spiral of quantum stages through which one might proceed up the hierarchical steps. However, like the scientific method, everyone need not proceed through every stage on every problem, and many students can jump over some of the stages. Other students may have to do additional work at a stage, or repeat an earlier stage before they are ready to move on. Therefore, we should be repeating or jumping over steps according to the readiness of the students. Some very creative students with sufficient scientific understanding should be able to leap to the upper levels very quickly. In this article, we presented a creative program for encouraging creative ability at the first level of the PEPC (general overlapped patterns). The same process could be applied to other scientific studies of phenomena, in physics or other areas.

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